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## **CROATIAN CONTRIBUTION TO REGIONAL COOPERATION FOR LIMITED AREA MODELLING CENTRAL EUROPE (RC LACE)**

### **Modeliranje na ograničenom području u Središnjoj Europi: doprinos hrvatskih znanstvenika**

YONG WANG  
LACE Program Manager

Zentralanstalt für Meteorologie und Geodynamik,  
Hohe Warte 38, A-1190 Vienna, Austria

*wang@zamg.ac.at*

RC LACE (Regional cooperation for limited area modelling Central Europe) is a Central European collaborative program which pursues extensive scientific and technical collaboration in the field of very high resolution operational numerical weather prediction (NWP) for weather research, forecast and application. The LACE consortium (<http://www.rclace.eu>) consists of the National Meteorological and Hydrological Services of Austria (Central Institute for Meteorology and Geodynamics), Croatia (Meteorological and Hydrological Service), Czech Republic (Czech Hydrometeorological Institute), Hungary (Meteorological Service of Hungary), Romania (National Meteorological Administration), Slovakia (Slovak Hydrometeorological Institute) and Slovenia (Environmental Agency of the Republic of Slovenia, Meteorological Office). The principle objectives of LACE are to develop and maintain a state of the art operational short-range NWP system by all the consortium members, to conduct scientific and technical research directed towards improving the quality of forecasts, to share the human resources on NWP research and to exchange observation data for NWP operation. All the LACE members are also the member of ALADIN (Aire Limitée Adaptation dynamique Développement InterNational) program and LACE is in close cooperation with HIRALM (High Resolution Limited Area Model) program. LACE was initiated in the beginning of 1990s, as the profound political changes in Europe in the late 1980s opened up new communication channels and brought great opportunities for co-operation in the Central European area. These opportunities for cooperation were recognized very soon by most Central European meteorological and hydrological services in the area of operational NWP which has always been extremely important for high impact weather warning and for numerous applications. They decided to work together in developing ALADIN NWP system in very close cooperation and coordination with Météo-France. It is essential that every national weather service runs their own NWP system operationally and provides the warning information tailored to end user's specific needs. In Central Europe, the reality is that the most countries are small and some of them are developing countries, they cannot have sufficient human resources and technical capacity to develop a state of the art operational NWP system by them alone.

In the last 25 years LACE has worked closely together with ALADIN and HIRLAM partners, the LACE members are running a state of the art NWP system and data assimilation operationally at high resolution from 2.5 - 5.0 km. LACE has largely contributed to the development of ALADIN NWP models (Bubnová et al. 1995), ALARO (<http://www.rclace.eu/?page=74>) and AROME (Applications of Research to Operations at Mesoscale, Seity et al. 2011). They have shared their human resources on research and development of ALADIN-LAEF (Limited Area Ensemble Forecasting, Wang et al. 2010, 2012), and exchanged their data in real time through observation preprocessing for LACE (OPLACE) for data assimilation and verification.

Croatian Meteorological and Hydrological Service (DHMZ) is one of the LACE founding member and an active part of LACE from the beginning. DHMZ has developed strong scientific and technical collaboration with LACE and contributed to its development with high dedication. DHMZ involved much in LACE leadership. Dijana Klarić had been program manager from 1999

to 2012. She involved Stjepan Ivatek-Šahdan in LACE management as data manager from 2003 to 2004 and Tomislav Kovačić as area leader for data assimilation from 2010 to 2012.

DHMZ has participated many LACE research and development actions. Together with other LACE colleagues, Klarić and Ivatek-Šahdan developed ALADIN spectral and surface blending method (Brozkova, Klarić, Ivatek-Šahdan et al. 2001) for the limited area model initialization that has entered to LACE operative configuration since the 2000. It has been one of the main component of data assimilation set up at some LACE countries. The blending has even become the backbone of the initial perturbation method for limited area model ensemble prediction system ALADIN-LAEF in its operational configuration (Wang et al. 2014). Furthermore, Ivatek-Šahdan helped to set up ALADIN-LAEF (Wang et al. including Ivatek-Šahdan 2011), Kalin worked on ALADIN common verification client-server application for synoptic scale verification at ARSO (Ljubljana), Kovačić implemented DDH (Diagnostics en Domaines Horizontaux) tool for ALARO and AROME.

There were many other numerous contributions from DHMZ. Some of them are: use of high-resolution dynamical adaptation in operational suite and research impact studies (Ivatek-Šahdan and Tudor 2004); tests of sub-grid scale orography representation, horizontal diffusion, radiation and cloudiness parameterization of ALADIN (Drvar et al. 2005, Tudor et al. 2005, Tudor 2010); flux-conservative thermodynamic equations in a mass-weighted framework (Catray et al. including Tudor 2007); diagnosis and tuning of the background error statistics in a variational data assimilation system (Boloni and Horvath 2010); alternative formulations for incorporating Lateral Boundary Data into Limited-Area Models (Tudor and Termonia 2010); investigation on numerical instability and stiffness in the ALADIN parameterization (Tudor 2013).

Further, DHMZ colleagues have conducted many case and impact studies on the performance of ALADIN, on ALADIN simulation on different weather systems, e.g. flash flood, bora, and over mountains and ocean (Ivančan-Picek and Jurčec 2002, 2003; Ivančan-Picek et al. 2003; Horvath and Ivančan-Picek 2003; Vukičević et al. 2005; Ivančan-Picek et al. 2005; Beg Paklar et al. 2005; Ivatek-Šahdan and Ivančan-Picek 2005, 2006; Kuzmić et al. 2006; Ivančan-Picek et al. 2006; Kozarić and Ivančan-Picek 2006; Bencetić et al. 2009; Martin et al. 2009; Rixen et al. 2009; Vandenbulcke et al. 2009; Vilibić et al. 2009; Horvath et al. 2009; Tudor and Ivatek-Šahdan 2010; Horvath et al. 2011; Stiperski et al. 2011; Renko et al. 2012; Mazzocco Drvar et al. 2012; Tudor et al. 2013; Mihanović et al. 2013; Janeković et al. 2014; Kalin et al. 2015).

The strong involvement and contribution of DHMZ demonstrates that LACE is a successful example of regional collaboration among small and medium national weather services on extensive scientific research and technical development in field of high resolution operational NWP. Cooperation on common research and development actions, active contribution to the model development and sharing resources and applications are the key factors for the success of LACE, which makes all the partners beneficial from the program.

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